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# Detection of Moisture and Moisture Related Phenomena from Skylab

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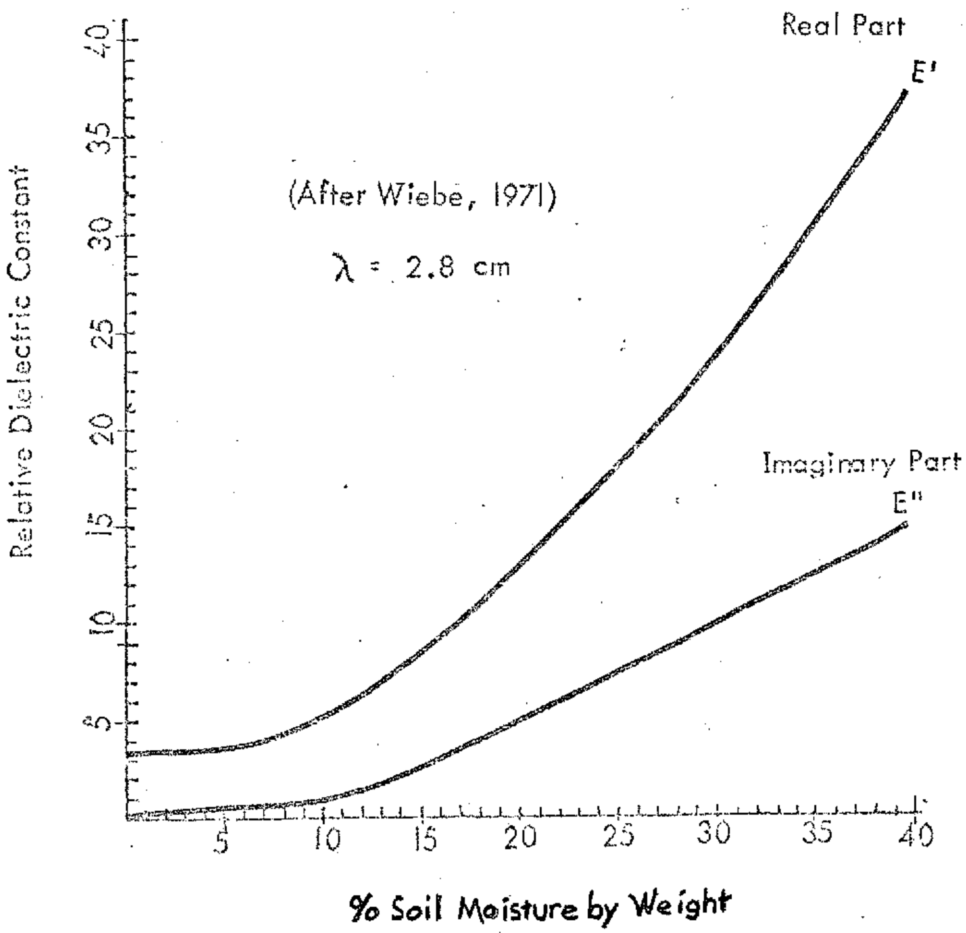
## SKIN DEPTH CALCULATIONS

Since the thickness of soil providing the electromagnetic radiation to be measured by remote sensors varies with moisture content and incident angle, microwave response to water content in a constant thickness of the soil is subject to this influence. The return of an active radar and the image of a passive radiometer depend largley on the complex dielectric constant of the ground and incident angle. It is important, therefore, to consider the skin depth of electromagnetic radiation in the ground which can be computed from a knowledge of the dielectric properties of soil and water.

The presence of water in most earth materials causes high attenuation of microwave radiation. Microwave radiation will, therefore, penetrate deeper in places where there is lower liquid water. The attenuation as a funciton of water content is valid for a large range of soil types but for relatively few of the other soil characteristics (Ulaby et al., 1973, Hoekstra and Delaney, 1974).

The exact nature of the influence of the water content of soil on the complex dielectric constant has not been well defined since slightly different results have been obtained by various investigators. Therefore, the several measurements of soil dielectric constant (Wiebe, 1971, Newton et al., 1974 and Teschanskii, et al., 1971) are shown in Figures 1 through 4. Each of these have been used to compute the skin depth. The skin depth of each soil sample was computed using the definition of



Real Part
E'
(After Wiebe, 1971)
λ = 2.8 cm
Imaginary Part
E"
Relative Dielectric Constant
5
10
15
20
25
30
35
40
% Soil Moisture by Weight


Figure I

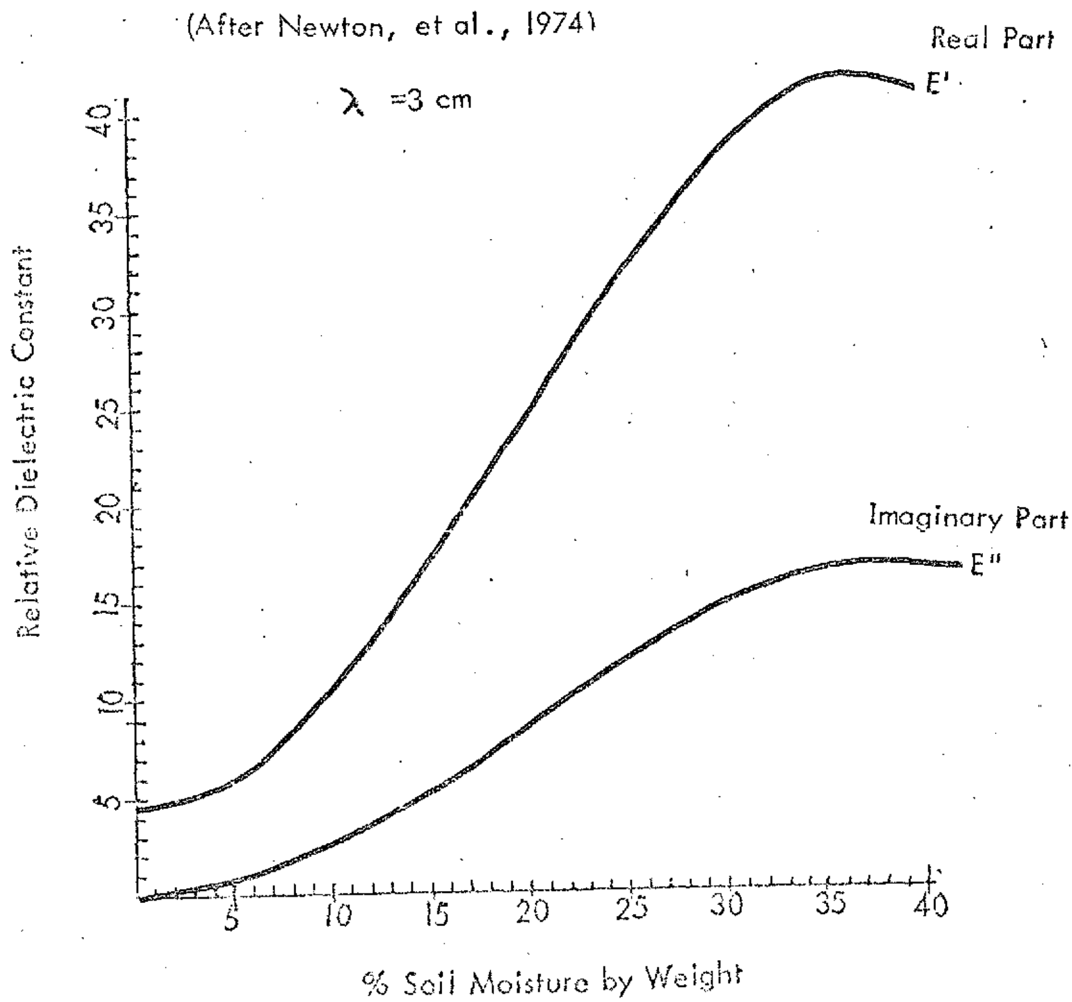
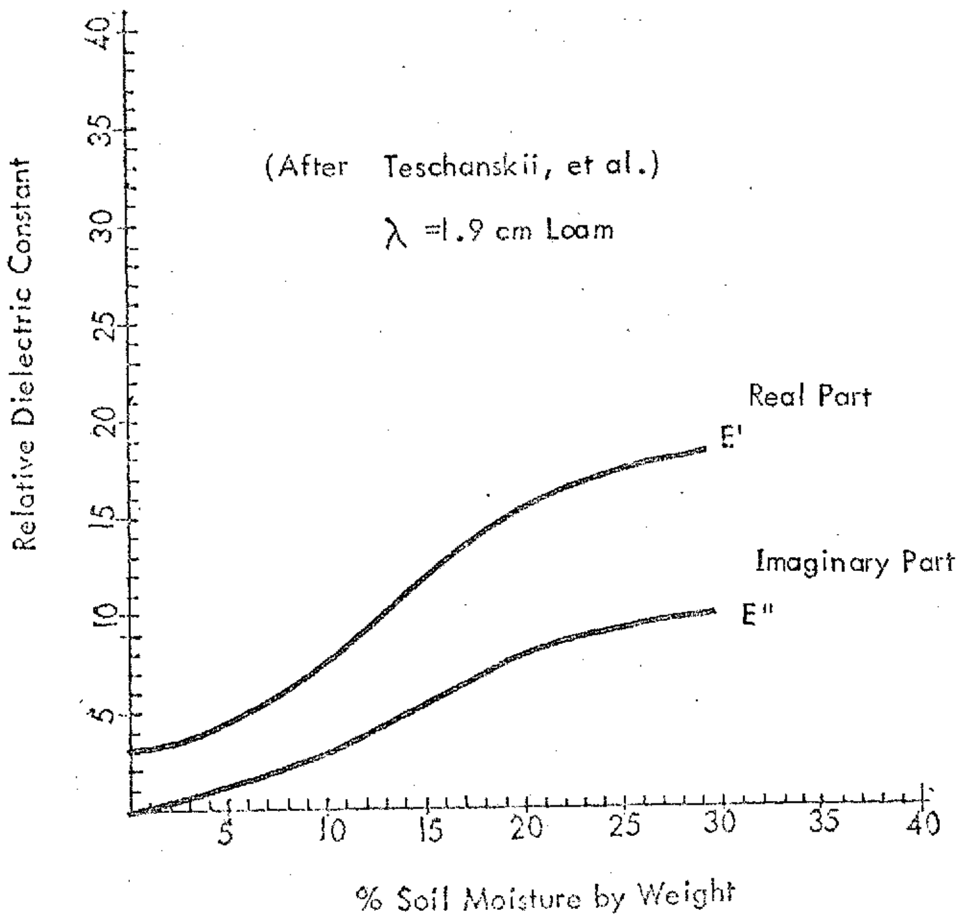

(After Newton, et al., 1974)
λ =3 cm
Real Part
E'
Imaginary Part
E"
Relative Dielectric Constant
40
35
30
25
20
15
10
5
5
10
15
20
25
30
35
40
% Soil Moisture by Weight

Figure 2



(After Teschanskii, et al.)
λ =1.9 cm Loam
Relative Dielectric Constant
40
35
30
25
20
15
10
5
Real Part
E'
Imaginary Part
E"
5
10
15
20
25
30
35
40
% Soil Moisture by Weight


Figure 3

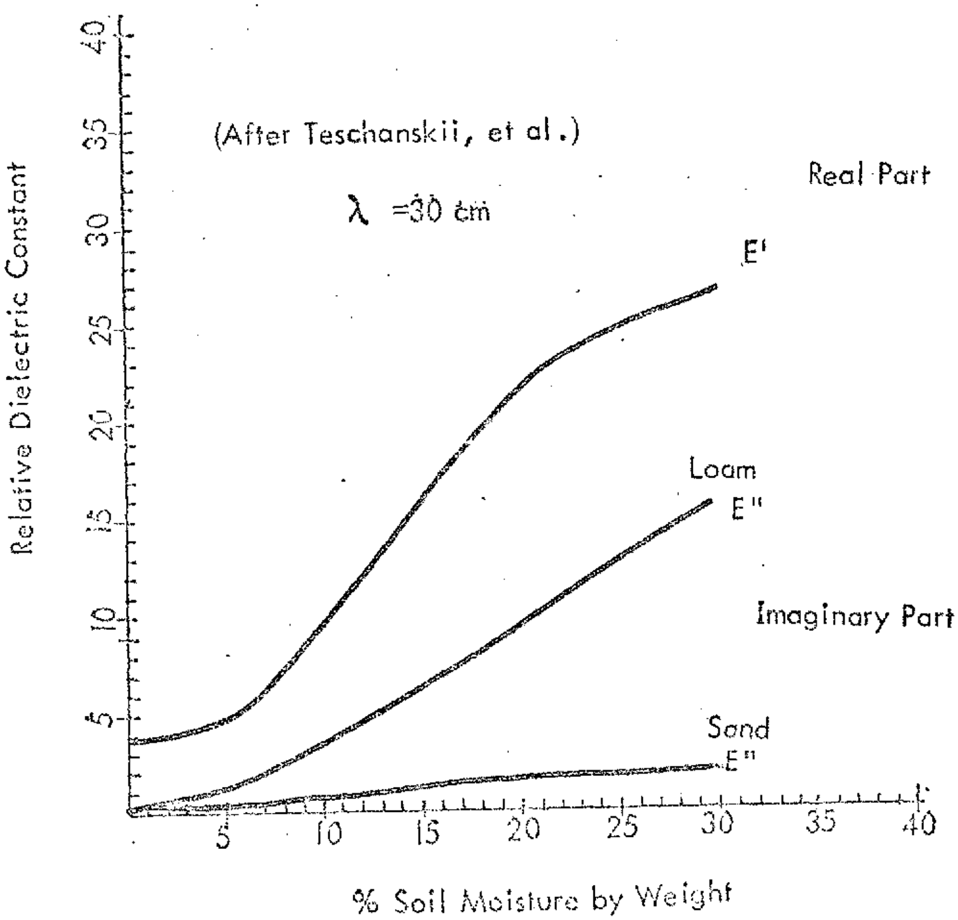
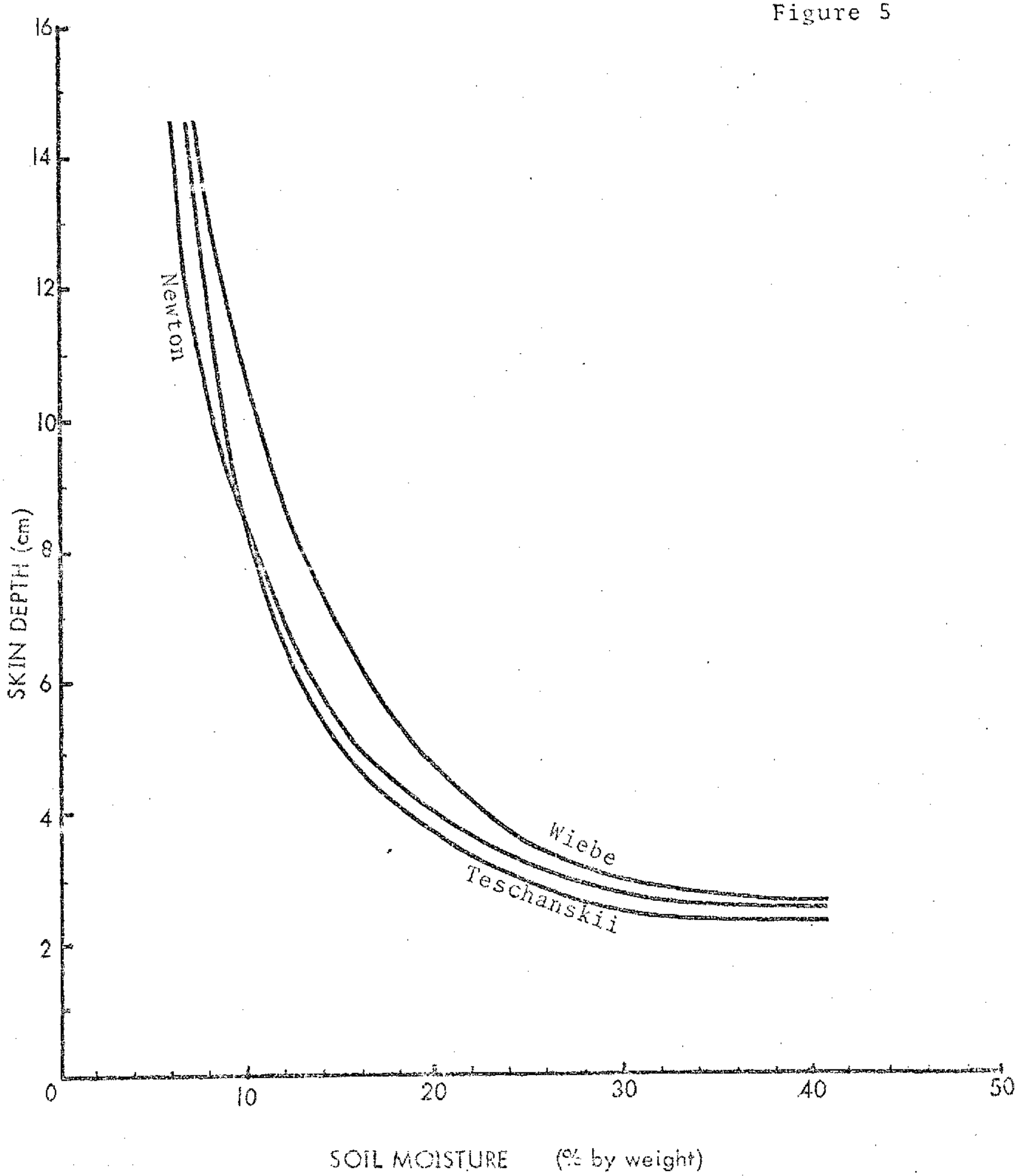

(After Teschanskii, et al.)
λ =30 cm
Real Part
E'
Loam
E"
Imaginary Part
Sand
E"
Relative Dielectric Constant
% Soil Moisture by Weight
5
10
15
20
25
30
35
40

Figure 4

Figure 5


16
14
12
10
8
6
4
2
0
10
20
30
40
50
SKIN DEPTH (cm)
SOIL MOISTURE (% by weight)
Newton
Wiebe
Teschanskii

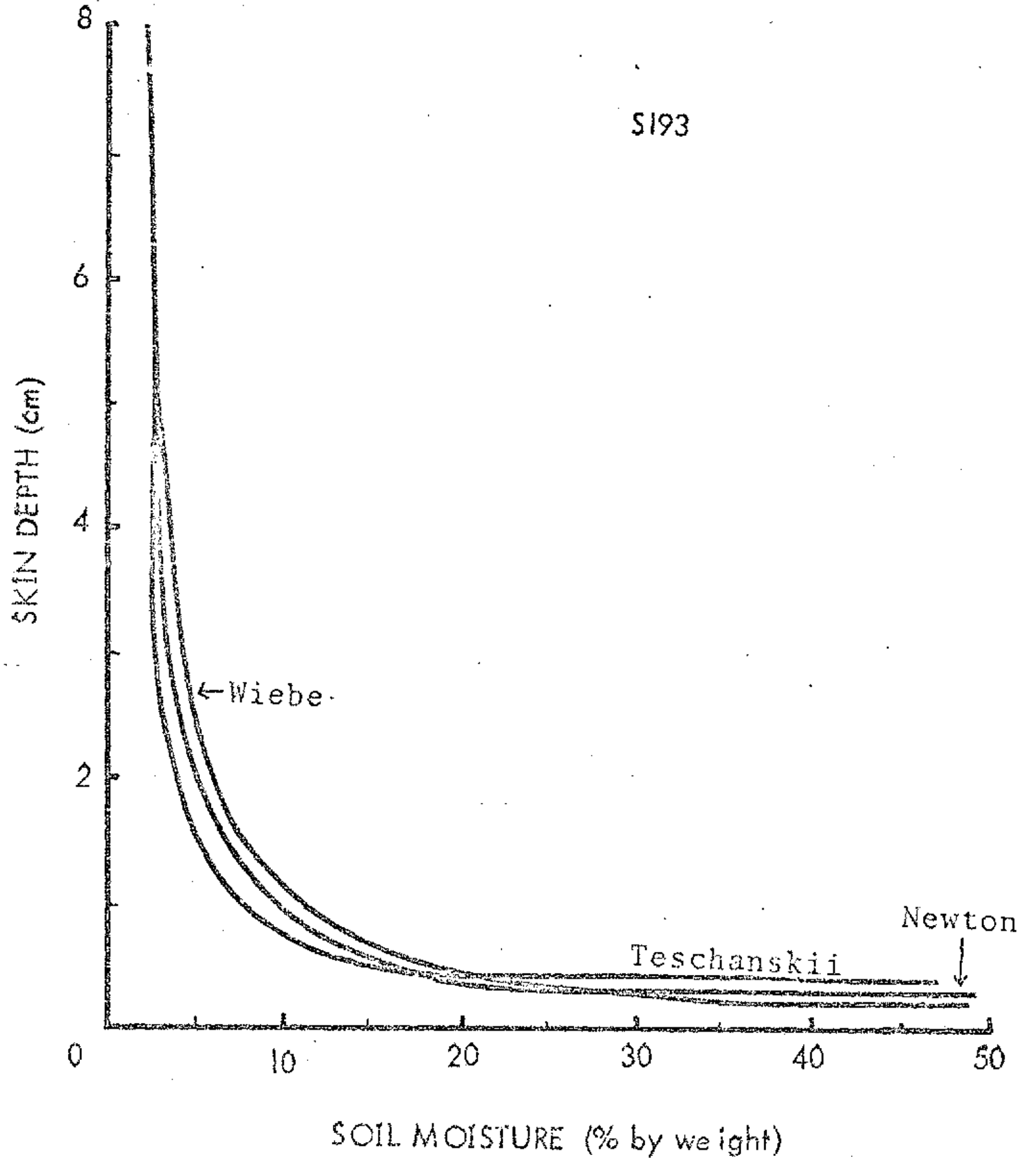

S193
SKIN DEPTH (cm)
8
6
4
2
0
10
20
30
40
50
SOIL MOISTURE (% by weight)
Wiebe
Teschanskii
Newton

Figure 6

skin depth ($\delta$) as the following equation:

$$\int_0^\delta \alpha(z)dz = 1$$

where z is depth of soil and $\alpha$ is attenuation coefficient in nepers/meter.

The skin depths of the 66 moisture profiles for the 6/5/73 pass over the Texas site were computed by considering cumulative attenuation of soil layers 0.1 cm thick for S194, Figure 5. For the S193 sensor, the skin depth was calculated using Snell's law of refraction (Ulaby et al., 1973). The results for the S193 are shown in Figure 6. These calculations are helpful in understanding the relationship between the microwave sensors and the moisture content at various depths within the soil. For the S194 radiometer, the radiation emitted from the soil is coming primarily from the first 2.5 cm if the soil is wet and from the first 15 cm if the soil is very dry. Correlations between the S194 radiometric temperature and the experimetnally determined soil moisture content of various layers have been best for the first 2.5 cm for four Skylab passes and for the first 5 cm for the fifth pass.

As expected, the skin depth of the shorter wavelength S193 instrument is not as great as for the S194 for the same moisture content as shown in Figures 5 and 6. Radiation is emitted from the first 2.5 cm of soil for all moisture contents except very dry soils. Radiation from wet soils comes from an even shallower layer. Therefore, in our future data analysis there seems to be no reason for trying to correlate the S193 data with soil moisture content deeper than the first 2.5 cm layer.

DETAILS OF S-193 BACKSCATTER FOOTPRINTS, 6/5/73

The center points of S193 backscatter footprints were located by latitude-longitude coordinates and were recorded on topographic sheets for the June 5, 1973 Texas site. Those points lying nearest to soil sample sites were determined and elliptical boundaries 13 x 15 km were drawn on topographic sheets to show the area covered by each footprint. The ellipses were then drawn on tracing paper. The tracing paper was placed on the topographic sheets and stream channels, both intermittent and continuous flowing streams, were drawn for each footprint. The length of the stream channels were then totaled for each ellipse.

The footprints were divided into four quadrants for the purpose of determining percent and direction of slope. To obtain the general direction of slope for each quadrant, arrows were drawn perpendicular to the contour lines. Where contour lines were irregular in direction such as in dissected areas, the general trend of the contours was used.

To determine the percent of slope for areas where contour lines were nearly straight and the distance between contours was unifrom, the distance was measured from the highest to the lowest contour line. The change in elevation was then divided by the measured distance. When the distance between coutour lines was irregular, an average distance was estimated within each footprint. Where slope varied greatly within a given footprint such as along an escarpment, these areas were indicated in the

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footprint and the maximum percent of slope was given.

Thus, each S193 footprint was studied in detail so that a better understanding of each point will be possible when the S193 backscatter coefficient is correlated with moisture content.

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